

Preliminary Report on Policy Issues and Research Recommendations of the United Nations International Conference on Near-Earth Objects (NEOs)

John L. Remo
St. James, New York.

Topics presented at the April 1995 United Nations International Conference on Near-Earth Objects are outlined and panel discussions are briefly summarized with emphasis on policy issues and research recommendations. Specific proposals based on an interpretation of international law and its relationship to the near-Earth object (NEO) hazard problem are suggested. Technical and research objectives to facilitate international cooperation for NEO discovery, exploration, and hazard mitigation are outlined.

Introduction

In April, 1995 a conference on near-Earth Objects (NEOs) was held at the United Nations world headquarters in New York city. Supporters of this conference included the National Aeronautics and Space Administration, the Planetary Society, and Sandia National Laboratories. The purpose of this plenary conference was to put into perspective recent discoveries in the natural sciences which describe the part played by Earth-crossing asteroids and comets (ECACs) in the extinction of a large range of species (e.g. from dinosaurs to ammonoids) and the resultant effect on the evolution of those mammalian ancestors from which Homo sapiens ultimately developed. These perspectives include the effects of past terrestrial impacts contained within the fossil record, current astronomical observations of NEOs, and future exploration missions to understand the properties of NEOs and the hazards they may pose to the planet Earth. Participants included scientists from both the major industrialized nations, as well as from many developing countries. It is anticipated that this representative cross-section of U. N. member states and the cooperative spirit of the meeting may provide a basis for future international cooperation in NEO research.

The conference was characterized by the open and rational analysis of the various discoveries of natural science and a willingness to share information associated with the collision of NEOs with the Earth in the past, present, and future. A considerable amount of observational data and information was exchanged during the first two days of formal sessions. During the third day fora were held to discuss NEO observations, exploration, and policy issues. This report briefly outlines the scientific topics reviewed at the formal session and some of the ideas presented at the discussion groups. The emphasis of the latter was on observations, exploration, and policy issues. The policy recommendations presented in this paper are primarily based on my interpretations of the group consensus and the current space treaties.

A Brief Summary of Some NEO Topics Covered at the Conference

Modern theories on the origin and evolution of the solar system all argue that NEOs (which are primarily Earth-crossing comets and asteroids or their ancient equivalents) have influenced the history of the Earth since its formation. Over the past few decades we have learned to recognize scars both on the Earth's surface as well as on other planets, moons, and asteroids in the solar systems as marking past asteroid and comet impacts (Chapman, 1995; Melosh, 1995, and Neukum and Ivanov, 1994; and Neukum 1995, Sharpton 1995). On the Earth the largest of these scars are over 100 km in diameter. The worldwide distribution of craters ranges in age from 2 billion years to about 4,000 years (Henbury), demonstrating that NEO impacts on our planet represent a continuing process (Grieve and Shoemaker, 1994 and Grieve, 1995). With the discovery of the global effects associated with the Cretaceous/Tertiary (K/T) boundary event (Alvarez et al, 1980; Sharpton 1995;) it appears likely that NEOs have also been influential in the evolution and extinction of many terrestrial species (Black, 1995; Jablonski, 1995; Smit, 1994 and 1995; and Ward 1995). Not only were the dinosaurs eliminated; it is also thought by some (Jablonski and Raup, 1995) that the K/T mass extinction caused a 70-80% reduction in biodiversity at the species level and a 50% reduction at the genus level. Such analyses suggest that some biotic factors that enhance survival during times of low extinction rates are ineffectual during mass extinctions. However, we note that the association of the K/T extinction with extraterrestrial impact is not universally held (Keller, 1995). Nonetheless, the overwhelming scientific evidence points to an extraterrestrial impact as the agent for the great extinctions at the K/T. This conclusion has recently been dramatically underscored by the impact of comet Shoemaker-Levy 9 on Jupiter (Ahrens and Harris, 1995; Crawford et al 1995; Hammel, 1995 and D. Levy 1995). Had any of these fragments impacted Earth, a global catastrophe would have ensued bringing enormous property damage and loss of life (Morrison 1995 and Toon et al, 1995). Fortunately, based on the established terrestrial impact crater record, it appears such an event is extremely unlikely, (about one chance in 6,000 over the next fifty years), but not impossible. Although the probability is small (and may even be correlated through planetary dynamics-Bottke et al, 1994; Rabinowitz et al, 1994; and Steel 1995), the consequences are so dire they cannot be ignored. To involve the world community with this issue of planetary importance is the reason the U N with the cooperation of the Office for Outer Space Affairs was chosen as a forum for this interdisciplinary conference.

Conference Objectives

As stated in the introduction, one of the reasons for calling the International Conference on NEOs was to present combined research results from several scientific disciplines describing how the human race was provided an opportunity to evolve from mammalian predecessors. That extraterrestrial objects could be demonstrated to dramatically influence the evolutionary course of terrestrial life is a powerful concept that provides unique perspectives on the unfolding of the human race. The relationship between adaptation and evolution becomes particularly interesting in this context. While biological adaptation can be interpreted through natural selection, accumulated changes at the gene level can generate evolutionary changes. From such models it can be understood how the impact of large NEOs, catastrophically disrupting the terrestrial biosphere, initiate substantial (catastrophic) geological changes on the surface of the Earth over extended periods of time and provide new boundary conditions for adaptation. These impacts modulate geological changes on the surface

of the Earth which is otherwise interpreted to have developed continuously and uniformly over long periods of time by plate tectonic activity. Thus, the NEO impact at the K/T boundary provides an exciting overlay to the interpretations of Darwin, Lyell, and Hutton which still provide the interpretive matrix of natural science. Following in this tradition of resolving the domains of uniformitarianism and catastrophism, the astronomers, planetary scientists, paleontologists, environmental scientists, and other scientists interpreted and restated the impact data from their own disciplinary perspective. In a sense, the conference was a celebration of interdisciplinary science whose objective was the cross calibration and interpretation of data from different disciplines. This activity served as a stimulus for gaining further knowledge through education, exploration, and research in the natural sciences as well as providing a warning of possible future hazards.

This conference also provided an example of how science and exploration are an important cultural endeavor that defines our civilization, bestowing a model for free enquiry that is the underpinning of self-government and its freedoms. From this perspective, one can interpret science as an endeavor worthy of societal support. Therefore, another objective of this conference was to initiate an organizational framework through which scientists, explorers, and amateur astronomers, in all countries can participate in research projects critical to human development and survival.

There is a singular reason why the United Nations was chosen as a venue for this conference. Since the initiation of the space age, the need to establish international cooperation for the peaceful uses of outer space was clearly perceived by the member states. Currently the United Nations is coordinating a large number of cooperative space activities at international, regional, and national levels. Most important in implementing this international cooperation in space are the treaties and principles governing the activities of states in the exploration and use of outer space as adopted by the United Nations General Assembly (United Nations Treaties and Principles on Outer Space, 1994). It is within this framework that the International Conference on Near-Earth Objects was convened. Therefore, a primary objective of this meeting was to interpret the NEO threat within the cooperative framework of existing guidelines of international space law. Such inclusion will essentially provide a mechanism for states which are parties to these treaties to include the possible threat from NEOs within these treaties. Other conference objectives including issues associated with cooperative space exploration, research, and education in the natural sciences are also compatible with this very important objective.

To carry out these tasks, this conference required assembling an extraordinary group of international scientists to discuss a broad range of scientific and technological problems associated with a NEO impact, as well as the encompassing humanistic aspects. The historical precedence of our scientific and educational institutions foster a tradition of inquiry and discovery for the advancement of all peoples. These shared ideals promote cooperation among nations, give guidance to leaders, and provide motivation for young people, who are the future, to work in an open way towards common goals. The very survival of our species depends on the appropriate use of our intellect to work together in a cooperative manner. To this end, space provides a unique challenge. In accepting this challenge, we must pursue our scientific goals with the utmost integrity, rigor, and humility, while also diligently communicating our findings to a literate public, from whom we ultimately draw our support. However, we must be careful not to over-react or seek temporary acceptance or prominence by promoting sensational or alarmist views in the pursuit of short term recognition and funding.

Interpretations

It is clear that the overall intent of the U.N. treaties and agreements on outer space are directed towards the peaceful exploration and utilization of space. It is also clear that nuclear and other weapons of mass destruction are prohibited from being placed in orbit around Earth or being stationed in space. However, if a NEO threatens Earth how can the mitigation be effectively carried out within the current framework of the treaties? Of course, Article 51 of the U.N. Charter gives member nations the right of self defense. But certainly a more specific protocol is needed to address the NEO hazard issue. This may be carried out through an extension of the U.N. outer Space treaties to include NEOs. A first step is to coordinate the identification and cataloging of NEOs. Second, is the identification of a clear and direct threat; this is a problem in NEO observation, identification, and tracking which requires adequate ground based observations sensitive to objects of magnitude 22 or greater. The third step is establishment of rapid and clear lines of communication regarding NEO hazards, which are already in place for certain space emergencies, TV direct broadcast satellites, radio communication satellites, reconnaissance satellites, etc. and need only be extended to cover NEOs. This will minimize the chance for misinterpretation of NEO motives and will facilitate, if necessary, a coordinated worldwide response. The next steps will involve an actual interaction with the threatening NEO. Such a response to the threatening NEO, if necessary and prudent, will depend on the availability of mitigation technology delivery systems and energy sources.

It may be argued that there may be more to fear from an apparently overzealous or unjustified desire by some to use weapons of mass destruction on a NEO body that may not be an immediate threat. The use of such a weapon may create a greater threat. Even worse is the deliberate, calculated misuse of assets whose ostensible purpose is for NEO mitigation. Such dilemmas will always be with us. Clearly, The NEO hazard threat cannot be used as a pretext for re-armament, and appropriate safeguards must be taken to minimize the threat of misuse.

If mitigation methods and devices are to be developed, safeguards and rigorous controls against their misuse must play a dominant role at every stage of their design, development, testing, and deployment. However, in the absence of specifically developed mitigation technology it would be prudent to have available that technology and hardware which can most effectively deal with an Earth threatening NEO. We must and can establish the appropriate custodial mechanisms that allow us to maintain those options which can best protect the Earth.

Finally, we must remember that the entire discipline of NEO studies and even their mitigation is driven by observations. Without a sky survey program, the discovery rate will not be adequate to provide even a minimal inventory of the threats from NEOs in the near term. Clearly, observational activities and imaging research (e.g., CCDs) must be supported as a first priority. Other research on materials and their interactions with shock waves and ionizing radiation, rockets, space systems and communications, and a general understanding of asteroid and comet properties must be supported in order to interpret observations and assess possible hazards and mitigation options. Science, technology, and education are all mutually supportive and must be adequately funded to achieve the requisite knowledge regarding NEO mitigation and the wisdom to effectively deal with the hazard aspect in a rational manner.

Conclusion

The hypotheses originally put forth by Alvarez et. al. (1980) that an extraterrestrial impact on the Earth about 66 million years ago caused massive extinctions, based on the best current natural science data available, is correct. That there are currently many thousands of Earth-crossing asteroids and comets that can do considerable environmental damage to the Earth and its inhabitants has also been shown. The impact of SL-9 on Jupiter provided a timely example of the devastation that could occur from such an impact. The question is how should the Earth deal with the possible NEO hazard?

It is therefore proposed to the United Nations that, as a first step, Articles V and XI in the 1967 Outer Space Treaty be considered to extend to cover NEOs. It is also suggested that the 1979 Agreement Governing Activities of States on the Moon and other celestial bodies be modified in order to be acceptable to additional Member States and that it be extended to include the NEO impact hazard.

Steps towards mitigation should focus on, in the order of priority:

1. A vigorous NEO sky search with adequate follow-up for objects of special significance.
2. Laboratory experiments on surrogate NEO materials emphasizing spectral observables (especially for passive comet-like materials) and their response to mechanical and radiative interactions.
3. Development of long range rockets to carry out flyby, orbital, and penetrator reconnaissance missions.
4. Maintenance of the scientific and technological capabilities of the academic and industrial bases and the research and development laboratories.

The views, interpretations and opinions presented in this paper are those solely of the author (JLR).

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References

1. All the references listed as 1995 in the text except those listed below are from the **International Conference on Near-Earth Objects**, and will be published in 1996 as the **Proceedings of the International Conference on Near-Earth Objects**.
2. Alvarez, L. W., Alvarez, W., Asaro, F., and Michel, H. V., *Extraterrestrial Cause for the Cretaceous-Tertiary Extinction*, **Science**, 208: 1095-1108 (1980).
3. Bottke, W.F. Jr, Nolan, N. C., Greenburg, R., and Kolvoord, R. A., *Collisional Lifetimes and Impact Statistics of Near-Earth Asteroids*, **Hazards Due to Comets and Asteroids**, 337-357, T. Gehrels ed., Tucson (1994).
4. Grieve, R. A. F., and Shoemaker, E. M., *The Record of Past Impacts on the Earth*, **Hazards Due to Comets and Asteroids**, 313-336, T. Gehrels ed., Tucson (1994).
5. Jablonski, D. and Raup, D. M., *Selectivity of End Cretaceous Marine Bivalve Extinctions*, **Science**, 268: 389-391 (1995).
6. Neukum, G. and Ivanov, B. A., *Cratering Distributions and Impact Probabilities on Earth from Lunar, Terrestrial-Planet, and Asteroid Cratering Data*, **Hazards Due to Comets and Asteroids**, 359-416, T. Gehrels, Tucson, (1994).
7. Rabinowitz, D. L., Bowell, E., Shoemaker, E. M., and Muinonen, K., *The Population of Earth-Crossing Asteroids*, *ibid*, 285-312, (1994)